VARIABLE STARS IN GALACTIC GLOBULAR CLUSTERS

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ABSTRACT

Based on a search of the literature up to May 2001, the number of known variable stars in Galactic globular clusters is approximately 3000. Of these, more than 2200 have known periods and the majority (approximately 1800) are of the RR Lyrae type. In addition to the RR Lyrae population, there are approximately 100 eclipsing binaries, 120 SX Phe variables, 60 Cepheids (including population II Cepheids, anomalous Cepheids and RV Tauri) and 120 SR/red variables. The mean period of the fundamental mode RR Lyrae variables is $0^{\rm d}.585$, for the overtone variables it is $0^{\rm d}.342$ ($0^{\rm d}.349$ for the first-overtone pulsators and $0^{\rm d}.296$ for the second-overtone pulsators) and approximately 30% are overtone pulsators. These numbers indicate that about 65% of RR Lyrae variables in Galactic globular clusters belong to Oosterhoff type I systems. The mean period of the RR Lyrae variables in the Oosterhoff type I clusters seems to be correlated with metal abundance in the sense that the periods are longer in the more metal poor clusters. Such a correlation does not exist for the Oosterhoff type II clusters. Most of the Cepheids are in clusters with blue horizontal branches.

Subject headings: stars: horizontal-branch — stars: oscillations — stars: variables: RR Lyrae, Cepheids, SX Phe — binaries: eclipsing — globular clusters: general

1. INTRODUCTION

Variable stars are useful standard candles for determining the distances to the Galactic globular clusters (GGCs) and it is important to know these distances for an understanding of the age, structure and formation of the Galaxy. As a result, there are many papers on the subject of variable stars in globular clusters. More than sixty years ago, Sawyer (1939) published a catalog of variable stars in GGCs to enable investigators interested in the topic to get a clear picture of exactly what work had been done in the area. The catalog listed 1116 variables in 60 clusters. Second and third editions of the catalog, with 1421 and 2119 entries respectively, were subsequently produced (Sawyer 1955, Sawyer Hogg 1973). Sawyer Hogg intended to publish a fourth edition, and in preparation for this, she recorded material from the relevant papers published between 1973 and 1988 on reference cards. After her death in 1993, the cards were placed with the University of Toronto Archives and Records Management Services (UTARMS) where they now reside. In 1997, an electronic version of the 1973 catalog was produced and the material from the 1973–1988 reference cards was included (Clement 1997).

Since 1988, there have been many papers on the subject of globular clusters and their variables. Furthermore, during this period CCD detectors have been widely used. Consequently, many new variables have been discovered, particularly in crowded central regions of clusters. Thus it is an appropriate time to update the catalog and prepare a summary of the material. To search the literature for papers published after 1988, we consulted volumes 49-58 and 61-68 of the Astronomy and Astrophysics Abstracts for the years 1989-1993 and 1994-1997 respectively, and for papers published after 1997, we consulted the NASA Astrophysics Data System. In this paper, we summarize the numbers and types of variable stars in GGCs. In addition, for the RR Lyrae variables and Cepheids, we illustrate how the periods relate to the clusters' metal abundance and horizontal branch morphology. The complete updated catalog can be obtained at the following website:

http://www.astro.utoronto.ca/people.html

2. SUMMARY OF THE DATA

In Table 1, we list the Galactic globular clusters which are known to contain variables. For each cluster, we list the horizontal branch ratio (HBR) and the metal abundance, [Fe/H]. The HB ratio, $(B - R)/(B + V + R)$, is a parameter devised by Lee (1990) to describe horizontal branch morphology. Both of these quantities were taken from the 1999 update to Harris's (1996) catalog of globular cluster parameters (http : //www.physun.physics.mcmaster.ca/Globular.html). The total number of variables in each cluster and the number for which periods have been determined is listed in column (3) and the main types of variables are indicated in columns (4) to (9). These totals do not include any stars that are suspected or confirmed to be field stars. 'SX' (column 4) refers to the SX Phe type variables, stars in the region just above the ZAMS, that pulsate with periods less than $0^{\rm d}.2$. 'RR' (column 5) refers to RR Lyrae variables. Although many variables have been tentatively classified as RR Lyrae, we include here only the ones for which periods have been determined. 'Cep' and 'RV Tau' (column 6) refer to Cepheids (anomalous or population II) and RV Tauri variables. In general, we have classified stars with periods less than 1 day as RR Lyrae variables and stars with periods greater than 1 day as Cepheids. However, the actual threshold between these two groups of variables may be P=$0^{\rm d}.75$ or $0^{\rm d}.80$ (Wallerstein & Cox 1984, hereafter WC84; Gautschy & Saio 1996, hereafter GS96). The 'SR/Red' variables (column 7) are pulsating variables that have periods greater than 35 days and/or stars that have been classified as semi-regular or irregular. Column (8) lists the number of eclipsing binaries and in column (9), we cite the papers in which new information has been presented concerning the elements of the variables since Sawyer

Hogg's (1973) catalog. For most of the clusters, the totals of columns 4 to 8 are equal to or greater than the number of variables for which periods have been determined because many irregular variables do not have published periods. However, in some cases (e. g. M15), there are 'unclassified' variables with published periods.

There are 147 clusters in the Harris catalog, but only 102 are known to have variable stars. This does not mean that there are none in the other 45 because not all clusters have been searched. Also, with the use of CCD detectors and new search techniques, for example, the image subtraction method introduced by Alard & Lupton (1998), many new variables will be discovered, even in the clusters that have already been studied.

In Figure 1, we plot the period-frequency distributions for pulsating variables in globular clusters. In the top panel, stars with periods less than 1 day are plotted. The stars with $P<0^{d}.2$ are considered to be SX Phe variables. Most of the others are RR Lyrae variables, but a few of the longer period ones may be anomalous Cepheids or population II Cepheids. The middle panel includes the Cepheid and RV Tauri variables with periods in the range 1 to 50 days. The RV Tauri stars are plotted with their pulsation periods. The plot also includes two stars (one in ω Centauri and one in NGC 5466) with periods less than 1 day and classified as anomalous Cepheids. In the lower panel, variables with pulsation periods between 35 and 440 days are shown.

Figure 2 shows the period-frequency distribution for the eclipsing binaries. The majority of these stars have periods less than 1 day and about half are of the W Ursa Majoris type. Rucinski (2000) recently reviewed the literature on W UMa-type binaries and found that at least one-third of his sample were foreground stars. We have not included any of these foreground stars in Figure 2 or in Table 1.

3. THE SX PHE VARIABLES

Rodríguez & López-González (2000) published a catalog of SX Phe stars in GGCs and in nearby galaxies. They showed that there seems to be a correlation between mean periods and metallicity in the sense that the periods of the SX Phe variables are longer in stellar systems with higher metallicity. They also pointed out that all of the SX Phe variables have been discovered in the last 20 years and that there has been a great increase in their numbers during the last few years. As more clusters are studied, the number of SX Phe stars will undoubtedly increase further and we will be able to gain a better understanding of how their properties relate to the properties of the clusters to which they belong. An interesting point to note from the data of Table 1 is that, in four of the 21 clusters known to have SX Phe stars, no RR Lyrae stars have been detected. Three of these, NGC 4372, 6397 and 6752, have extremely blue horizontal branches and the other one, M71, has an extremely red HB. Since SX Phe stars are near the main sequence, it seems that they are not affected by horizontal branch morphology.

4. THE RR LYRAE VARIABLES

For the RR Lyrae variables, we have adopted a system of notation recently introduced by the MACHO consortium (Alcock et al. 2000, hereafter A00). 'RR0' instead of 'RRab' is used to designate fundamental mode pulsation, 'RR1' instead of 'RRc' for first-overtone, 'RR01' instead of 'RRd' for double-mode (fundamental and first-overtone), 'RR2' instead of 'RRe' for second-overtone pulsation and 'RR12' for double-mode (first and second-overtone). No RR12 variables have yet been identified in globular clusters, but A00 found three in the LMC. In Table 2, we list information concerning the periods of RR Lyrae variables in the GGCs: in columns (2) and (3), the number of fundamental mode pulsators and their mean periods, in columns (4) and (5), the number of first overtone pulsators and their mean periods, in column (6) and (7), the number of second overtone pulsators and their mean periods, in columns (8) and (9), the number of double-mode pulsators and their mean periods and in column (10), the mean fundamentalized period. Since the dominant mode of pulsation for most of the double-mode variables is the first-overtone, we list the mean overtone periods in column (9). The fundamentalized period was computed assuming period ratios: $P_1/P_0 = 0.745$ and $P_2/P_1 = 0.804$, typical period ratios derived by A00 for the RR01 and RR12 variables in the LMC. The possibilty that RR2 variables really exist has been the subject of some discussion in the literature. In recent studies of ω Cen and NGC 5897, Clement & Rowe (2000, 2001) showed that the RR1 and RR2 variables seem to separate into two sequences in the period-luminosity and period-amplitude plots. Therefore, to decide whether an overtone pulsator should be classified as RR1 or RR2, we consulted the period-amplitude relation of Clement & Rowe (2000). However, it is not always easy to discriminate between RR1 and RR2 variables in the period-amplitude plot because the models of Bono et al. (1997) predict that the period-amplitude relation for RR1 stars shows a characteristic 'bell' shape with amplitudes decreasing at shorter periods. Thus in some cases, our classifications are uncertain.

According to Table 2, the mean period for all of the RR0 variables in GGCs is $0^{\mathrm{d}}.585$ and for the overtone variables, it is $0^{\mathrm{d}}.342$ ($0^{\mathrm{d}}.349$ for the first-overtone and $0^{\mathrm{d}}.296$ for the second-overtone). Approximately 30% of the RR Lyrae variables are overtone pulsators. In calculating the mean overtone periods, we have included the RR01 variables as first-overtone pulsators because the first-overtone is generally their dominant mode of pulsation. These figures indicate that most of the GGC RR Lyrae variables are in Oosterhoff type I systems.[2]

[2]Oosterhoff (1939, 1944) recognized that globular clusters could be classified into two groups according to the period-frequency distribution of their RR Lyrae variables. He showed that the mean periods for the RR0 variables were $\sim 0^{\mathrm{d}}.55$ in the type I (OoI) clusters and

In their investigation of the MACHO data for LMC RR Lyrae variables, Alcock et al. (1996, hereafter A96) reached a similar conclusion.

In Figure 3, we show the period-frequency distributions for the RR Lyrae variables separated according to Oosterhoff type. In assigning the Oosterhoff type, we assume that all clusters for which the mean period of the RR0 stars is $<0\overset{d}{.}60$ belong to group I and that clusters for which the mean RR0 period is $\geq 0\overset{d}{.}60$, with the exception of Ruprecht 106, belong to group II. The study of the RR Lyrae variables in Rup 106 by Kaluzny et al. (1995) shows that its period-amplitude relation is similar to that of M3 and so we have classified it as OoI. Pal 5, which has no RR0 stars, is considered to be OoI on the basis of the mean period of its RR1 variables. When the period-frequency data are separated by Oosterhoff type, it is possible to see that there are two peaks in the distribution for the overtone pulsators, particularly in the OoII clusters. This is an effect that A96 noted in the MACHO LMC data for RR Lyrae variables and they attributed it to pulsation in the second-overtone mode. The mean period for the 936 RR0 stars in the OoI clusters is $0\overset{d}{.}559$, for the 232 RR1 and RR01 stars, it is $0\overset{d}{.}326$, for the 29 RR2 stars, it is $0\overset{d}{.}281$, the mean fundamentalized period is $0\overset{d}{.}533$, and 22% of the variables are overtone pulsators. The equivalent figures for the OoII clusters are $0\overset{d}{.}659$ for 333 RR0, $0\overset{d}{.}368$ for 268 RR1 and RR01, $0\overset{d}{.}306$ for 44 RR2, $0\overset{d}{.}580$ for $< P_f >$ and 48% are overtone pulsators. These numbers are comparable to what Oosterhoff (1939) found for the two groups, but the percentage of the (lower amplitude) overtone pulsators[3] has increased.

$\sim 0\overset{d}{.}65$ in the OoII clusters. He also found that, in the OoII clusters, the percentage of overtone pulsators was higher than in the OoI clusters.

[3]When Oosterhoff discovered the two cluster groups in 1939, he used the terms ‘c-type’ and ‘a- and b-type’ for first-overtone and fundamental-mode pulsators. This is because it was not recognized until the following year that the c-type variables were pulsating in the

In Figures 4 to 7, we plot [Fe/H] and HBR versus the mean periods of the RR0 and RR1[4] variables. Since any correlations are more significant if the sample of RR Lyrae variables is greater, we plot in the upper panels only the systems with at least 15 RR0 stars (Figures 4 and 5) or at least 15 RR1 stars (Figures 6 and 7) and then in the lower panels we include systems with fewer variables. Similar plots for the mean 'fundamentalized' periods are shown in Figures 8 and 9. In Figure 4, there seems to be a correlation between [Fe/H] and mean period for the OoI clusters (i.e. the ones with $< P0 >$ less than $0\overset{d}{.}60$) in the sense that the periods are longer in the more metal poor clusters. However, the correlation breaks down when the mean period is greater than $0\overset{d}{.}60$, i.e. in the OoII clusters. A similar trend can be seen for the mean fundamentalized periods in Figure 8. The mean period is correlated with [Fe/H] for clusters with $< P_f >$ less than about $0\overset{d}{.}56$ (OoI clusters), but not for clusters with longer periods. The period-[Fe/H] correlation can also be seen among the RR1 mean periods less than $0\overset{d}{.}34$ in Figure 6, but it is not as marked as in Figures 4 and 8 because OoI clusters do not have so many RR1 variables.

Until recently, it has been assumed that metal rich clusters have RR Lyrae variables with short periods and therefore belong to the OoI class, but investigations of NGC 6388 and NGC 6441 by Pritzl et al. (2000) and Layden et al. (1999) have shown that these two clusters are exceptions to the rule. Both have [Fe/H]~ -0.6 which makes them the most metal rich clusters with RR Lyrae variables, but their $< P0 >$ values are greater than $0\overset{d}{.}70$.

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first-overtone mode (Schwarzschild 1940).

[4]No plots were made for the RR2 stars because there are not enough of them. ω Cen is the only cluster in which we have classified more than 5 stars as RR2. We considered the possibility that our assumed mean periods for the RR1 stars would be in error if the stars we considered to be RR2 variables were in fact RR1 variables. However, it turned out that such errors would not be large enough to affect the appearance of Figures 6 and 7.

Because of these long periods, we classify these clusters as OoII. The discrepant 'crosses' in the middle and lower panels of Figure 4, the lower panel of Figure 6 and the middle and lower panels of Figure 8 are the points for these clusters. In fact, NGC 6441 does not even appear in Figure 8. Since it has no known RR1 stars, its mean fundamentalized period is so long ($0^{\mathrm{d}}.768$) that it is off the scale of the diagram. The metal rich cluster 47 Tuc (NGC 104) also has an RR0 variable with a period longer than $0^{\mathrm{d}}.70$ (Carney et al. 1993), but it does not appear in Figures 4 or 8 because it is the only RR Lyrae variable in the cluster.

The importance of [Fe/H] for determining properties of globular cluster RR Lyrae variables has already been questioned by Clement & Shelton (1999, hereafter CS99) and by Lee & Carney (1999b). Lee & Carney compared M2 and M3, two clusters with similar metal abundance and found substantial differences in their RR Lyrae populations. CS99 studied the period V-amplitude relation for RR0 stars with 'normal' light curves[5] in several globular clusters and found that the V amplitude for a given period was a function of Oosterhoff type, but not a function of [Fe/H]. The OoII clusters in their sample were M9 and M68, but they also included two M92 RR0 stars for which published CCD photometry was available. Subsequently, Clement (2000a) showed that the RR0 variables in in the OoII cluster M55 and in the metal rich clusters 47 Tuc and NGC 6441, as well as the RR0 stars brighter than $V = 14.65$ in ω Cen (the OoII variables) all fit the OoII relation of CS99. In the meantime, Papadakis et al. (2000) confirmed that the RR0 variables in the OoII cluster NGC 6426 fit the OoII period-amplitude relation derived by CS99. More recently, Kopacki (2001) compared the period-amplitude relations for the RR0 variables in three OoII clusters with different [Fe/H], M2, M53 and M92, and verified that there was no significant period-shift. Thus period-shift for the OoII clusters is not a function of metal

[5]The compatibility test of Jurcsik & Kovacs (1996) was used to assess whether or not the light curve of a star was normal.

abundance. The P-A relation plotted by Alves et al. (2001) for NGC 5986 also seems to coincide with the CS99 OoII relation. An interesting feature of their diagram is that the P-A relation for NGC 5986 is shifted to longer periods than the fiducual ridge line they plot for M15. Since M15 is more metal poor than NGC 5986, they were expecting the M15 RR0 stars to have longer periods. M15 which is often considered the prototype for OoII clusters seems to have a P-A relation that is different from the others! As noted above, Figures 4, 6 and 8 also illustrate that the periods for OoII clusters do not depend on [Fe/H]. It therefore seems well established that, for the OoII clusters, mean periods and period shifts are not correlated with [Fe/H].

However, the situation is different in the OoI clusters. We have seen from Figures 4 and 8 that there is a correlation between mean period and [Fe/H] for the OoI clusters. The OoI clusters that CS99 used for their study were M3 amd M107. They acknowledged that the transition between fundamental and first-overtone mode pulsation occurs at a shorter period in M107 compared to M3. However, the short period fundamental mode pulsators in M107 did not have 'normal' light curves. As a result, there was no period shift between the period-amplitude relations for 'normal' RR0 stars in the two clusters. Later, Kaluzny et al. (2000) performed a similar analysis for the RR0 variables in M5 and found that its P-A relation was shifted to shorter periods compared with M3. Borissova et al. (2001) reached the same conclusion in a recent study of NGC 6229. Thus in the OoI clusters, mean periods and period shifts seem to be correlated with [Fe/H], but in the OoII clusters they are not. This is another important difference between clusters of the two Oosterhoff groups and may indicate something about the evolutionary status of their RR Lyrae variables.

In Figures 5, 7 and 9, HBR is plotted against mean period. In Figure 5, we see that clusters with [Fe/H]< -1.6 and blue horizontal branches (HBR> 0) belong to the Oosterhoff type II class. However, having a blue HB does not necessarily guarantee an

OoII classification because there are OoI clusters with HBR>0.5. On the other hand, no cluster with HBR<0 belongs to the OoII class.[6] According to Lee et al. (1990), the RR Lyrae variables in OoII clusters have evolved away from the ZAHB, and as a result, have longer periods and higher luminosities than the ones in OoI clusters, which are ZAHB stars. Furthermore, Lee (1990) calculated models illustrating that for metal poor clusters with HBR>0.65, the bluer the HB morphology of the cluster, the longer the periods should be. To test this hypothesis, Catelan (1994) made plots of mean periods and HBR using the cluster data available at the time and found no correlation. It is interesting to note that with the new data plotted in Figure 5, the cluster with the longest mean RR0 period (M2) is the one with the bluest horizontal branch. Another feature to note in these diagrams, particularly Figure 9, is that when all the clusters are considered, there is a weak correlation between mean period and HBR.

5. THE POPULATION II CEPHEIDS

The period-frequency distrubution for the Cepheids and RV Tauri variables is shown in the middle panel of Figure 1. The four RV Tauri variables, plotted with their pulsation periods which range from about 29 days for V1 in ω Cen to 46 days for V17 in M28 seem to form a long period extension to the Cepheids. The gap in the period at around 10 days has an evolutionary origin. The longer period variables are either on a blueward excursion from the AGB during He-shell flashes or they are on the way towards the white dwarf cooling region (GS96, Gingold 1976). Their periods range from about 12 days (V17 in M14) to 29

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[6]The cluster with HBR$=-0.8$ and $< P(RR0) >, < P_f >= 0.617$ is Rup 106 which we have classified as OoI. This anomalous cluster was shown to be extremely young by Chaboyer et al. (1992).

days (V21 in M28).

The stars with periods less than 10 days have often been referred to as BL Her stars, but GS96 pointed out that this is not an appropriate name because BL Her itself is not metal deficient. They prefer to call them AHB1 stars because they have evolved from the blue HB and are on the way to the AGB. They cross the instabilty strip at higher luminosities than the RR Lyrae variables and therefore have longer periods. It is expected that their periods should increase with time and Wehlau & Bohlender (1982) have confirmed this to be the case. Four of the stars in the short period group are considered to be anomalous Cepheids. These are V19 in NGC 5466 (Zinn & Dahn 1976) and three ω Cen stars classified by Kaluzny et al. (1997c). According to WC84, anomalous Cepheids (ACs) have periods between about $0\overset{\mathrm{d}}{.}50$ and 3 days, but are too luminous for their periods. The high luminosities can be accounted for if they have larger masses than other population II Cepheids and these large masses are thought to occur because they are formed by the coalescence of one or more stars. Two of the globular cluster ACs in our sample (Ogle # 161 in ω Cen and V19 in NGC 5466) have periods less than a day.

In Figure 10, we plot [Fe/H] and HBR versus period for the individual Cepheids and RV Tauri variables. There is no correlation between period and [Fe/H], but most have [Fe/H] between -1.25 and -1.75. In fact, all but one of the Cepheids are found in clusters that are more metal poor than -1.25. Horizontal branch morphology is an important parameter for determining whether or not a cluster will have Cepheids. Generally they occur only in clusters with blue horizontal branches and this can be seen in Figure 10. However, we also see in Figure 10 that two clusters with HBR< 0 have Cepheids. These are NGC 2808 and Pal 3, and in both cases the Cepheids have periods less than 4 days. Another interesting feature of the diagram is that, among the Cepheids in clusters with HBR less than 0.5, the periods tend to be longer in clusters with bluer horizontal branches.

It is often assumed that the boundary between RR Lyrae variables and Cepheids occurs at a period of one day. However as we noted in section 2, it is probably shorter. WC84 and GS96 have suggested that it may occur at periods as short as $0\overset{d}{.}75$ or $0\overset{d}{.}80$. Also, some clusters have bright variables with periods of about $0\overset{d}{.}5$ and light curve morphology that is significantly different from RR Lyrae variables with the same period. Examples of such stars are V47, V68 and V123 in ω Cen, V76 in M5 and V10 in NGC 5897. Nemec et al. (1994) have suggested that V68 in ω Cen might be an anomalous Cepheid or a first-overtone AHB1 variable. There is also some uncertainty about classification at the longer periods. V2 in NGC 6712 has been classified as semi-regular by Rosino (1966, 1978) but Barnes & Dupuy (1975) considered it to be an RV Tauri variable. As high precision light curves become available for more stars, it may be possible to use light curve morphology, in addition to color and luminosity, to distinguish between the different types of pulsating variables.

6. THE SR AND RED VARIABLES

The SR and red variables are the pulsating giant stars that Rosino (1978) designated as yellow semi-regular, red semi-regular, irregular or Mira variables in his review of variable stars in globular clusters. Whitelock (1986) made a plot of bolometric magnitude versus the log of the fundamental period for cluster variables with periods greater than 1 day and pointed out that the relationship for the yellow and red variables might form an extension to the population II Cepheid P-L relation.

Since not all authors have designated a specific classification for variables with longer periods, we have included in column 7 of Table 1 the stars classified as semi-regular or irregular variables and all the stars with published periods greater than 35 days (excluding RV Tauri variables). These types of stars have not been well surveyed in the Galactic globular clusters because most search programs are designed to optimize detection and period determination for variables with periods less than one day. Thus our sample is probably incomplete. Periods have been published for some, but not all of these stars because of the irregular nature of their variation. Many of the 'unclassified' variables for which periods have not been determined (column 3 of Table 1) may belong in this category. The period-frequency plot in the bottom panel of Figure 1 shows that only five globular cluster variables have periods greater than 300 days, but according to the General Catalogue of Variable Stars[7] (Kholopov 1985a,b, 1987), periods greater than 300 days are not uncommon among field stars. Also, in a study of Mira variables in the Galactic bulge, Whitelock (1990) reported periods ranging up to 720 days with most between 360 and 560 days. This is probably a metallicity effect. Mira variables with such long periods do not occur in metal poor systems like globular clusters. However, in a study of the MACHO data for red giants in the LMC, Wood et al. (1999) have shown that there are red variables with periods up to about 1000 days. Because the MACHO observations of the LMC were made throughout the year, for a few years, variations on such a long time scale could be readily detected. Thus, as we have noted above, our sample of SR/red variables is undoubtedly incomplete.

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[7]The GCVS is also available at: http://www.sai.msu.su/groups/cluster/gcvs/gcvs/

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REFERENCES

Alard, C. & Lupton, R. H. 1998, ApJ, 503, 325

Alcock, C. *et al.* 1996, AJ, 111, 1146 (A96)

Alcock, C. *et al.* 2000, ApJ, 542, 257 (A00)

Alves, D. R., Bond, H. E. & Onken, C. 2001, AJ, 121, 318

Bakos, G. Á., Benkő, J. M. & Jurcsik, J. 2000, Acta. Astron. 50, 221

Bailyn, C. D., Rubenstein, E. P., Slavin, S. D., Cohn, H., Lugger, P., Cool, A. M. & Grindlay, J. E. 1996, ApJ, 473, L31

Barnes, T. G. & Dupuy, D. L. 1975, ApJ, 200, 364

Blanco B. M. & Blanco, V. M. 1997, AJ, 114, 2596

Bono, G., Caputo, F., Castellani, V. & Marconi, M. 1997, A&AS, 121, 327

Borissova, J., Catelan, M., Spassova, N., & Sweigart, A. V. 1997, AJ, 113, 692

Borissova, J., Catelan, M., & Valchev, T. 2001, MNRAS, 324, 77

Borrisova, J., Ivanov, V. D. & Catelan, M. 2000, IBVS, 4919

Borrisova, J., Spassova, N., Catelan, M. & Ivanov, V. D. 1998, in A Half Century of Stellar Pulsation Interpretation: A Tribute to Arthur Cox, ed. P. A. Bradley & J. A. Guzik (ASP Conf. Ser. 135; San Francisco: ASP), 188

Brocato, E., Castellani, V. & Ripepi, V. 1996, AJ, 111, 809

Buonnano, R., Buscema, G., Corsi, C. E., Iannicola, G. & Fusi Pecci, F. 1984, A&AS, 56, 79

Butler, D., Dickens, R. J. & Epps, E. 1978, ApJ, 225, 148

Butler, R. F., Shearer, A., Redfern, R. M., Colhoun, M., O'Kane, P., Penny, A. J., Morris, P. W., Griffiths, W. K. & Callum, M. 1998, MNRAS, 296, 379

Cannon, R. D. & Stobie, R. S. 1973, MNRAS, 162, 227

Cacciari, C. 1984a, AJ, 89, 231

Cacciari, C. 1984b, AJ, 89, 1082

Caputo, F., Castellani, V., Marconi, M. & Ripepi, V. 1999, MNRAS, 306, 815

Carney, B. W., Fullton, L. K., & Trammell, S. R. 1991, AJ, 101, 1699

Carney, B. W., Storm, J. & Williams, C. 1993, PASP, 105, 294

Catelan, M. 1994, AJ, 107, 2077

Chaboyer, B., Sarajedini, A. & Demarque, P. 1992, ApJ, 394, 515

Chu, Y.-H. 1977, Chinese Astronomy 1, 302

Chu, Y.-H., Clement, C. M., Sawyer Hogg, H. & Wells, T. R. 1984, In Cepheids: Theory and Observations, IAU Coll. 82, ed. B. F. Madore, 264

Clement, C. 1997, AAS Newsletter, 84, 15

Clement, C. M. 2000a, in The Impact of Large-Scale Surveys on Pulsating Star Research, IAU Colloq. 176, ed. L. Szabados & D. W. Kurtz (ASP Conf. Ser. 203; San Francisco: ASP), 266

Clement, C. M. 2000b, in Amateur-Professional Partnerships in Astronomy, ed. J. R. Percy & J. B. Wilson (ASP Conf. Ser. 220; San Francisco: ASP), 93

Clement, C. M., Bezaire, J. & Giguere, D. 1995a, AJ, 110, 2200

Clement, C. M., Dickens, R. J. & Bingham. 1979, AJ, 84, 217

Clement, C. M., Dickens, R. J. & Bingham, E. A. 1995b, AJ, 110, 2195

Clement, C. M., Ferance, S. & Simon, N. R. 1993, ApJ, 412, 183

Clement, C. M. & Hazen, M. 1989, AJ, 97, 414

Clement, C. M., Ip, P. & Robert, N. 1984, 89, 1707

Clement, C. M. & Nemec, J. M. 1990, JRASC, 84, 434

Clement, C. M., Nemec, J. M., Robert, N., Wells, T. Dickens, R. J. & Bingham, E. A. 1986, AJ, 92, 825

Clement, C., Panchhi, P. & Wells, T. R. 1982 AJ, 87, 1491

Clement, C. & Rowe, J. 2000, AJ, 120, 2579

Clement, C. & Rowe, J. 2001, AJ, 122, (September issue)

Clement, C. M. & Sawyer Hogg, H. 1977a, IBVS 1333

Clement, C. M. & Sawyer Hogg, H. 1977b, AJ, 82, 968

Clement, C. M. & Sawyer Hogg, H. 1978, AJ, 83, 167

Clement, C. M. & Sawyer Hogg, H. & Wells, T. R. 1980, AJ, 85, 1604

Clement, C. M. & Sawyer Hogg, H. & Wells, T. R. 1985, AJ, 90, 1238

Clement, C. M. & Sawyer Hogg, H. & Yee, A. 1988, AJ, 96, 1642

Clement, C. M. & Shelton, I. 1996, AJ, 112, 618

Clement, C. M. & Shelton, I. 1997, AJ, 113, 1711

Clement, C. M. & Shelton, I. 1999, ApJ, 515, L85

Cool, A. M., Grindlay, J. E., Cohn, H. N., Lugger, P. M. & Bailyn, C.D. 1998, ApJ, 508, L75

Corwin, T. M., Carney, B. W. & Allen, D. M. 1999a, AJ, 117, 1332

Corwin, T. M., Carney, B. W. & Nifong, B. G. 1999b, AJ, 118, 2875

Cudworth, K. M. 1988, AJ, 96, 105

Cudworth, K. M. & Rees, R. 1990, AJ, 99, 1491

Demers, S. & Wehlau, A. 1977, AJ, 82, 620

Deutsch, E. W., Margon, B. & Anderson, S. F. 1999, AJ, 118, 2888

Deutsch, E. W., Margon, B. & Anderson, S. F. 2000, ApJ, 530, L21

Drissen, L. & Shara, M. M. 1998, AJ, 115, 725

Edmonds, P.D., Grindlay, J. E., Cohn, H. & Lugger, P. 1996, ApJ, 468, 241

Edmonds, P.D., Grindlay, J. E., Cohn, H. & Lugger, P. 2001, ApJ, 547, 829

Fourcade, C. R., Laborde, J. R., Puch, A. A., Colazo, J. R. & Arias, J. C. 1975, IBVS, 1077

Fourcade, C. R., Laborde, J. R. & Yurquina, E. 1978, IBVS, 1380

Fox, M. W. 1982, MNRAS, 199, 715

Gautschy, A. & Saio, H. 1996, ARA&A, 34, 551 (GS96)

Geffert, M., Aurière, M., Ilovaisky, S. A. & Terzan, A. 1989, A&A, 209, 423

Gerashchenko, A. N., Kadla, Z. I. & Malakhova, Y. N. 1997, IBVS, 4418

Gingold, R. A. 1976, ApJ, 204, 116

Goranskij, V. P. 1976, Per. Zv. Supp, 3, 1

Goranskij, V. P. 1978, Per. Zv., 20, 555

Gratton, R. G. & Ortolani, S. 1984, A&AS, 57, 177

Harris, H. C. 1993, AJ, 106, 604

Harris, W. E. 1996, AJ, 112, 1487

Hartwick, F. D. A., Barlow, D. J. & Hesser, J. E. 1981, AJ, 86, 1044

Hazen, M. L. 1989, AJ, 97, 771

Hazen, M. L. 1991, AJ, 101, 170

Hazen, M. L. 1993a, AJ, 106, 1055

Hazen, M. L. 1993b, AJ, 105, 559

Hazen, M. L. 1994, AJ, 107, 1793

Hazen, M. L. 1996, AJ, 111, 1184

Hazen, M. L. & Hesser, B. H. 1986, AJ, 92, 1094

Hazen-Liller, M. L. 1985, AJ, 90, 1807

Hesser, J. E. 1980, IBVS 1758

Jeon, Y.-B., Kim, S.-L., Ho, L. & Gyoon, M. 2000, IBVS, 4970

Jørgensen, H. E. & Hansen, L. 1984, A&A, 133, 165

Jurcsik, J. & Kovács, G. 1996, A&A, 312, 111

Kadla, Z. I., Brocato, E., Piersimoni, A., Gerashchenko, A. N. & Malakhova, Y. N. 1995, A&A, 302, 723

Kadla, Z. I. & Geraschenko, A. N. 1982, Izv. Glav. Astron. Obs. Pulkovo, Astrometr. Astrofiz., 199, 86

Kadla, Z. I., Gerashchenko, A. N. & Malakhova, Y. N. 1996, IBVS, 4414

Kadla, Z. I., Gerashchenko, A. N. & Yablokova, N. V. 1980, Astron. Tsirk. 1136, 5

Kadla, Z. I., Geraschenko, A. N., Yablokova, N. V., Irkaev, B. N. 1987, Astron. Tsirk. 1502, 7

Kadla, Z. I., Gerashchenko, A. N., Yablokova, N. V. & Spasova, N. 1984, 1314, 1

Kadla, Z. I., Yablokova, N. V., Gerashchenko, A. N. & Spasova, N. 1983, Per. Zv. 21, 827

Kaluzny, J. 1996, A&AS, 120, 83

Kaluzny, J. 1997, A&AS, 122, 1

Kaluzny, J., Hilditch, R., Clement, C. & Rucinski, S. M. 1998a, MNRAS, 296, 347

Kaluzny, J. & Krzemiński, W. 1993, MNRAS, 264, 785

Kaluzny, J., Krzemiński, W. & Mazur, B. 1995, AJ, 110, 2206

Kaluzny, J., Krzemiński, W., & Nalezyty, M. 1997a, A&AS, 125, 337

Kaluzny, J., Kubiak, M., Szymański, A., Udalski, A., Krzemiński, W. & Mateo, M. 1996, A&AS, 120, 139

Kaluzny, J., Kubiak, M., Szymański, A., Udalski, A., Krzemiński, W. Mateo, M. & Stanek, K. 1997b, A&AS, 122, 471

Kaluzny, J., Kubiak, M., Szymański, A., Udalski, A., Krzemiński, W. Mateo, M. & Stanek, K. 1997c, A&AS, 125, 343

Kaluzny, J., Kubiak, M., Szymański, A., Udalski, A., Krzemiński, W. Mateo, M. & Stanek, K. Z. 1998b, A&AS, 128, 19

Kaluzny, J., Olech, A. & Stanek, K. Z. 2001, AJ, 121, 1533

Kaluzny, J., Olech, A., Thompson, I., Pych, W., Krzemiński, W., & Schwarzenberg-Czerny, A. 2000, A&AS, 143, 215

Kaluzny, J., Thompson, I. B. & Krzemiński, W. 1997d, AJ, 113, 2219

Kaluzny, J., Thompson, I., Krzemiński, W., & Pych, W. 1999, A&A, 350, 469

Kholopov, P. N. 1974, Astron. Circ. 848, 8

Kholopov, P. N. 1977, Per. Zv. 20, 313

Kholopov, P. N., Samus', N. N., Frolov, M. S., Goranskij, V. P., Gorynya, N. A., Kireeva, N. N., Kukarkina, N. P., Kurochkin, N. E., Medvedeva, G. I., Perova, N. B., Shugarov, S. Yu. 1985a, Gen. Cat. Var. St. vol I, Moscow: Nauka

Kholopov, P. N., Samus', N. N., Frolov, M. S., Goranskij, V. P., Gorynya, N. A., Kazarovets, E. V., Kireeva, N. N., Kukarkina, N. P., Kurochkin, N. E., Medvedeva, G. I., Perova, N. B., Rastorguev, A. S., Shugarov, S. Yu. 1985b, Gen. Cat. Var. St. vol II, Moscow: Nauka

Kholopov, P. N., Samus', N. N., Frolov, M. S., Goranskij, V. P., Gorynya, Karitskaya, E. A., N. A., Kazarovets, E. V., Kireeva, N. N., Kukarkina, N. P., Medvedeva, G. I., Pastukhova, E. N., Perova, N. B., Shugarov, S. Yu. 1987, Gen. Cat. Var. St. vol III, Moscow: Nauka

Kopacki, G. 2000, A&A, 358, 547

Kopacki, G. 2001, A&A, 369, 862

Kovács, G., Shlosman, I. & Buchler, J. R. 1986, ApJ, 307, 593

Kravtsov, V. V. 1988, Astron. Tsirk. 1526, 8

Kravtsov, V. V. 1991, Astron. Lett. 17, 455

Kravtsov, V. V. 1992, Soviet Astron. Lett. 18, 246

Kravtsov, V. V., Samus, N. N., Alcaino, G., & Liller, W. 1994, Astron. Lett. 20, 339

Layden, A. C., Ritter, L. A., Welch, D. L. & Webb, T. M. A. 1999, AJ, 117, 1313

Layden, A. C. & Sarajedini, A. 2000, AJ, 119, 1760

Lee, J.-W. & Carney, B. W. 1999a, AJ, 117, 2868

Lee, J.-W. & Carney, B. W. 1999b, AJ, 118, 1373

Lee, S.-W. 1974, Observatory, 94, 74

Lee, S.-W. 1977a, A&AS, 27, 367

Lee, S.-W. 1977b, A&AS, 28, 409

Lee, Y.-W. 1990, ApJ, 363, 159

Lee, Y.-W., Demarque, P. & Zinn, R. 1990, ApJ, 350, 155

Liller, M. H. 1975, ApJ, 201, L125

Liller, M. H. 1976, AJ, 81, 832

Liller, M. H. 1977, AJ, 82, 711

Liller, M. H. 1978, IBVS, 1527

Liller, M. H. 1981, AJ, 86, 1204

Liller, M. H. 1983a, AJ, 88, 404

Liller, M. H. 1983b, AJ, 88, 1463

Liller, M. H. & Lichten, S. M. 1978a, AJ, 83, 41

Liller, M. H. & Lichten, S. M. 1978b, AJ, 83, 1070

Liller, M. H. & Liller, W. 1976, ApJ, 207, L109

Liller, M. H. & Sawyer Hogg, H. 1976, AJ, 81, 628

Lloyd Evans, T. 1978, private communication to Helen Sawyer Hogg

Lloyd Evans, T. & Menzies, J. W. 1977, MNRAS, 178, 163

Malakhova, Y. N., Gerashchenko, A. N. & Kadla, Z. I. 1997a, IBVS, 4434

Malakhova, Y. N., Gerashchenko, A. N. & Kadla, Z. I. 1997b, IBVS, 4457

Marinchev, E. K. 1983, Per. Zv. 22, 65

Mateo, M., Harris, H. C., Nemec, J. & Olszewski, E. W. 1990, AJ, 100, 469

Mazur, B., Kaluzny, J. & Krzemiński, W. 1999, MNRAS, 306, 727

Meinunger, I. 1980, Mitt. Veranderl. Sterne, 8, 185

Menzies, J. 1974, MNRAS, 168, 177

Millis, A. J. & Liller, M. H. 1980, AJ, 85, 235

Nemec, J. M., Linell Nemec, A. F. & Lutz, T. E. 1994, AJ, 108, 222

Nemec, J. & Mateo, M. 1990, in Confrontation between Stellar Pulsation and Evolution, ed. C. Cacciari & G. Clementini (ASP Conf. Ser. 11; San Francisco: ASP), 64

Nemec, J. M., Mateo, M., Burke, M. & Olszewski, E. W. 1995a, AJ, 110, 1186

Nemec, J. M., Mateo, M. & Schombert, J. M. 1995b, AJ, 109, 618

Niss, B. Jørgensen, H. E. & Lausten, S. 1978, A&AS, 32, 387

Olech, A., Kaluzny, J., Thompson, I. B., Pych, W., Krzemiński, W. & Schwarzenberg-Czerny, A. 2001, MNRAS, 321, 421

Olech, A., Kaluzny, J., Thompson, I. B., Pych, W., Krzemiński, W. & Schwarzenberg-Czerny, A. 1999a, AJ, 118, 442

Olech, A., Woźniak, P. R., Alard, C., Kaluzny, J. & Thompson, I. B. 1999b, MNRAS, 310, 759

Oosterhoff, P. Th. 1939, Observatory, 62, 104

Oosterhoff, P. Th. 1944, BAN, 10, 55

Osborn, W. 2000a, AJ, 119, 2902

Osborn, W. 2000b, AJ, 120, 2730

Papadakis, I., Hatzidimitriou, D., Croke, B. F. W. & Papamastorakis, I. 2000, AJ, 119, 851

Park, N.-K. & Nemec, J. M. 2000, AJ, 119, 1803

Pinto, G & Rosino, L. 1973, Mem. Soc. Astron. Ital., 44, 255

Pinto, G & Rosino, L. 1977, A&AS, 28, 427

Pinto, G, Rosino, L. & Clement, C. M. 1982, AJ, 87, 635

Pritzl, B., Smith, H. A., Catelan, M. & Sweigart, A. V. 2000, ApJ, 530, L41

Pych, W., Kaluzny, J., Krzemiński, W., Schwarzenberg-Czerny, A. & Thompson, I. B. 2001, A&A, 367, 148

Rees, R. F. & Cudworth, K. M. 1991, AJ, 102, 152

Reid, N. 1996, MNRAS, 278, 367

Rodríguez, E. & López-González, M. J. 2000, A&A, 359, 597

Rosino, L. 1966, ApJ, 144, 903

Rosino, L. 1978, Vistas in Astronomy, 22, part 1, 39

Rucinski, S. M. 2000, AJ, 120, 319

Russev, R. & Russeva, T. 1979a, IBVS, 1534

Russev, R. M. & Russeva, T. S. 1979b, Per. Zv. 21, 169

Russeva, T., Iliev, L. & Russev, R. 1982, IBVS, 2223

Russeva, T. & Russev, R. 1980, IBVS, 1769

Russeva, T. S. & Russev, R. M. 1983, Per. Zv., 22, 49

Rutily, B. & Terzan, A. 1977, A&AS, 30, 315

Samus, N. N., Kravstov, V. V., Pavlov, M. V., Shokin, Y. A., Alcaino, G. & Liller, W. 1995, Soviet Astron. Lett. 21, 528

Sandquist, E. L., Bolte, M., Stetson, P. B. & Hesser, J. E. 1996, ApJ, 470, 910

Sawyer, H. B. 1939, Publ. David Dunlap Obs., 1, No. 4

Sawyer, H. B. 1955, Publ. David Dunlap Obs., 2, No. 2

Sawyer Hogg, H. 1973, Publ. David Dunlap Obs., 3, No. 6

Sawyer Hogg, H. & Wehlau, A. 1980, AJ, 85, 148

Schwarzschild, M. 1940, Harvard College Obs. Circ., 37

Shokin, Y. A. & Samus, N. N. 1996, Astron. Lett. 22, 761

Silbermann, N. A. & Smith, H. A. 1995, AJ, 110, 704

Silbermann, N. A., Smith, H. A., Bolte, M. & Hazen, M. L. 1994, AJ, 107, 1764

Spinrad, H., Smith, M. G. & Harlan, E. 1974, ApJ, 192, 405

Stetson, P. B.& West, M. J. 1994, PASP, 106, 726

Sujarkova, O. G. & Shugarov, S. Y. 1981, Per. Zv., 21, 505

Terzan, A. & Rutily, B. 1975, A&A, 38, 307

Thompson, I. B., Kaluzny, J., Pych, W. & Krzemiński, W. 1999, AJ, 118, 462

Walker, A. R. 1994, AJ, 108, 555

Walker, A. R. 1998, AJ, 116, 220

Walker, A. R. & Mack, P. 1986, MNRAS, 220, 69

Walker, A. R. & Nemec, J. M. 1996, AJ, 112, 2026

Wallerstein, G. & Cox, A. N. 1984, PASP, 96, 677 (WC84)

Wehlau, A. 1990, AJ, 99, 250

Wehlau, A. & Bohlender, D. 1982, AJ, 87, 780

Wehlau, A. & Butterworth, S. 1990, AJ, 100, 686

Wehlau, A. & Demers, S. 1977, A&A, 57, 251

Wehlau, A., Fahlman, G. G., Rucinski, S. M., Shi, J. & Thompson, I. 1996, IBVS, 4394

Wehlau, A., Flemming, T., Demers, S. & Bartolini, C. 1977, IBVS, 1361

Wehlau, A. & Froelich, N. 1994, AJ, 108, 134

Wehlau, A., Liller, M. H., Demers, S. & Clement, C. 1978, AJ, 83, 598

Wehlau, A., Liller, M. H., Clement, C. & Wizinowich, P. 1982, AJ, 87, 1295

Wehlau, A. & Sawyer Hogg, H. 1977, AJ, 82, 137

Wehlau, A. & Sawyer Hogg, H. 1978, AJ, 83, 946

Wehlau, A. & Sawyer Hogg, H. 1982, IBVS, 2171

Wehlau, A. & Sawyer Hogg, H. 1985, AJ, 90, 2514

Wehlau, A., Sawyer Hogg, H. & Butterworth, S. 1990, AJ, 99, 1159

Wehlau, A., Slawson, R. W. & Nemec, J. M. 1999, AJ, 117, 286

Welty, D. E. 1985, AJ, 90, 2555

Whitelock, P. A. 1986, MNRAS, 219, 525

Whitelock, P. A. 1990, in Confrontation between Stellar Pulsation and Evolution, ed. C. Cacciari & G. Clementini(ASP Conf. Ser. 11; San Francisco: ASP), 365

Wood, P. R., Alcock, C., Allsman, R. A., Alves, D., Axelrod, T. S., Becker, A. C., Bennett, D. P., Cook, K. H., Drake, A. J., Freeman, K. C., Griest, K., King, L. J., Lehner, M. J., Marshall, S. L., Minniti, D., Peterson, B. A., Pratt, M. R., Quinn, P. J., Stubbs, C. W., Sutherland, W., Tomaney, A., Vandehei, T. & Welch, D. L. 1999, in Asymptotic Giant Branch Stars, IAU Symp. 191, ed. T. Le Bertre, A. Lèbre & C. Waelkens (San Francisco: ASP), 151

Yan, L. & Reid, I. N. MNRAS, 1996, 279, 751

Yao, B.-a. 1986, Ap&SS, 119, 41

Yao, B.-a. 1987, Messenger, 50, 33

Yao, B.-a. 1990, IBVS, 3431

Yao, B.-a. 1991, IBVS, 3622

Yao, B.-a. 1993, IBVS, 3846

Yao, B.-a. & Qin, D. 1993, IBVS, 3920

Yao, B.-a., Tong, J.-h. & Zhang, C.-s. 1988, Acta Astron. Sinica, 29, 243

Yao, B.-a., Yin, J.-s. & Guo, Z.-h. 1981, Acta Astron. Sinica, 1, 311

Zinn, R. & Dahn, C. C. 1976, AJ, 81, 527

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FIGURE CAPTIONS

Fig. 1.— Period-frequency distribution for pulsating variables in Galactic globular clusters. The upper panel shows the distribution for stars with periods less than 1 day. The stars with periods less than $0^{\mathrm{d}}.20$ are SX Phe variables. Most of the others are RR Lyrae variables, but some of the longer period variables may be anomalous Cepheids or population II Cepheids. In the middle panel, the Cepheids and RV Tauri variables are plotted. The periods plotted for the RV Tauri stars are their pulsation periods. Also included are two anomalous Cepheids (one in ω Cen and one in NGC 5466) with periods less than a day. In the lower panel, the distribution for pulsating variables with periods between 50 and 440 days is shown.

Fig. 2.— Period-frequency distribution for eclipsing binary stars in the Galactic globular clusters.

Fig. 3.— Period-frequency distribution for RR Lyrae variables in clusters of Oosterhoff type I (upper panel) and Oosterhoff type II (lower panel).

Fig. 4.— Plots of [Fe/H] (from Table 1) versus mean period for the globular cluster RR0 variables. In the upper panel, only clusters with at least 15 RR0 variables are included and in the lower panels clusters with at least 10 and at least 5, respectively are included. Filled circles represent clusters that have red horizontal branches, i.e. HBR=[(B-R)/(B+V+R)]<0 and open circles represent clusters with HBR>0. Crosses represent clusters for which HBR has not been determined. (For ω Cen, a mean [Fe/H] value, -1.62, has been adopted.)

Fig. 5.— Plots of HBR (from Table 1) versus mean period for the globular cluster RR0 variables. In the upper panel, only clusters with at least 15 RR0 variables are included and in the lower panels clusters with at least 10 and at least 5, respectively are included. Filled circles represent clusters that have [Fe/H]≥ -1.6 and open circles represent clusters with [Fe/H]< -1.6.

Fig. 6.— Plots of [Fe/H] (from Table 1) versus mean period for the globular cluster RR1 variables. We include the RR01 stars here as well because their dominant mode of pulsation is generally the first overtone. In the upper panel, only clusters with a total of at least 15 RR1 and RR01 variables are included and in the lower panels clusters with at least 10 and at least 5, respectively are included. The symbols are the same as in Figure 4.

Fig. 7.— Plots of HBR (from Table 1) versus mean period for the globular cluster RR1 and RR01 variables. In the upper panel, only clusters with a total of at least 15 RR1 and RR01 variables are included and in the lower panels clusters with at least 10 and at least 5, respectively are included. The symbols are the same as in Figure 5.

Fig. 8.— Plots of [Fe/H] (from Table 1) versus mean fundamentalized period for the globular cluster RR Lyrae variables. In the upper panel, only clusters with at least 15 RR Lyrae variables are included and in the lower panels clusters with at least 10 and at least 5, respectively are included. The symbols are the same as in Figure 4.

Fig. 9.— Plots of HBR (from Table 1) versus mean fundamentalized period for the globular cluster RR Lyrae variables. In the upper panel, only clusters withat least 15 RR Lyrae variables are included and in the lower panels clusters with at least 10 and at least 5, respectively are included. The symbols are the same as in Figure 5.

Fig. 10.— Plots of [Fe/H] (upper panel) and HBR (lower panel) versus pulsation period for the individual Cepheids and RV Tauri variables in GGCs. In the upper panel, the symbols are the same as in Figure 4. In the lower panel, the symbols are the same as in Figure 5.

TABLE CAPTIONS

Table 1. Numbers and Types of Variable Stars in Galactic Globular Clusters

Table 2. Mean Periods of RR Lyrae Variables in Galactic Globular Clusters

Table 1. Numbers and Types of Variable Stars in Galactic Globular Clusters

Cluster	HBR/[Fe/H]	No./ (periods)	SX	RR	Cep or RVTau	SR or Red	Ecl	Ref
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
NGC 104/47Tuc	-0.99/-0.76	50/(37)	3	1	0	14	19	1,2,3,4
NGC 288	0.98/-1.24	10/(10)	6	2	0	1	1	5,6
NGC 362	-0.87/-1.16	13/(8)	0	7	0	1	0	7
NGC 1261	-0.71/-1.35	20/(19)	0	18	0	1	0	8,9
NGC 1851	-0.36/-1.22	32/(29)	0	29	0	0	0	10,11,12,13
NGC 1904/M79	0.89/-1.57	8/(3)	0	3	0	1	0	
NGC 2298	0.93/-1.85	4/(4)	0	4	0	0	0	14,15
NGC 2419	0.86/-2.12	41/(33)	0	31	1	4	0	16
NGC 2808	-0.49/-1.15	5/(3)	0	2	1	2	0	17
Pal 3	-0.50/-1.66	12/(1)	0	0	1	0	0	18,19,20
NGC 3201	0.08/-1.58	92/(77)	0	77	0	0	0	21,22
Pal 4	-1.00/-1.48	2/(2)	0	0	0	2	0	
NGC 4147	0.55/-1.83	16/(9)	0	9	0	0	0	23
NGC 4372	1.00/-2.09	16/(13)	8	0	2	0	3	24
Rup 106	-0.82/-1.67	16/(16)	3	13	0	0	0	25
NGC 4590/M68	0.17/-2.06	44/(44)	2	42	0	0	0	26,27
NGC 4833	0.93/-1.79	23/(15)	0	14	0	2	0	28
NGC 5024/M53	0.81/-1.99	67/(60)	0	58	0	2	0	29,30
NGC 5053	0.52/-2.29	15/(14)	5	9	0	0	0	31
NGC 5139/ω Cen	— /-1.62	275/(249)	34	161	10	15†	29	32,33,34 35,36,37
NGC 5272/M3	0.08/-1.57	254/(187)	1	182	1	3	0	38,39,40 41,42,43

Table 1—Continued

Cluster	HBR/[Fe/H]	No./ (periods)	SX	RR	Cep or RVTau	SR or Red	Ecl	Ref
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
NGC 5286	0.80/-1.67	24/(13)	0	13	0	0	0	44,45,46
NGC 5466	0.58/-2.22	31/(30)	6	20	1	0	3	47,48
								49,50
NGC 5634	— /-1.82	7/(6)	0	6	0	0	0	51
IC 4499	0.11/-1.60	113/(98)	1	97	0	0	0	52,53,54
NGC 5824	0.79/-1.85	27/(7)	0	7	0	0	0	
Pal 5	-0.40/-1.43	5/(5)	0	5	0	0	0	
NGC 5897	0.86/-1.80	9/(9)	1	7	0	1	0	55,56,57
NGC 5904/M5	0.31/-1.29	158/(135)	5	126	2	1	1	58,59,60,61
								62,63,64
								65,66,67
NGC 5927	-1.00/-0.37	9/(5)	0	0	0	5	0	68
NGC 5946	— /-1.38	6/(2)	0	2	0	0	0	69
NGC 5986	0.97/-1.58	10/(8)	0	8	0	1	0	70,71
NGC 6093/M80	0.93/-1.75	8/(7)	0	6	1	0	0	72
NGC 6121/M4	-0.06/-1.20	67/(57)	4	40	0	1	8	73,74,75,76
								77,78,79
NGC 6101	0.84/-1.82	15/(0)	0	0	0	0	0	80
NGC 6144	1.00/-1.73	1/(0)	0	0	0	0	0	69
NGC 6139	0.91/-1.68	10/(4)	0	4	0	0	0	81
NGC 6171/M107	-0.73/-1.04	23/(22)	0	22	0	0	0	82,83
NGC 6205/M13	0.97/-1.54	29/(18)	0	5	5	8	0	84,85,86
								87,87,89

Table 1—Continued

Cluster	HBR/[Fe/H]	No./ (periods)	SX	RR	Cep or RVTau	SR or Red	Ecl	Ref
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
NGC 6218/M12	0.97/-1.48	1/(1)	0	0	1	0	0	90,91
NGC 6229	0.24/-1.43	47/(42)	0	38	2	0	2	92,93
NGC 6235	0.89/-1.40	4/(4)	0	3	0	0	1	94
NGC 6254/M10	0.98/-1.52	4/(2)	0	0	2	1	0	95
NGC 6266/M62	0.32/-1.29	89/(74)	0	74	0	0	0	96
NGC 6273/M19	— /-1.68	5/(5)	0	1	4	0	0	97
NGC 6284	— /-1.32	10/(9)	0	6	2	2	0	98
NGC 6287	0.98/-2.05	3/(0)	0	0	0	0	0	99
NGC 6293	0.90/-1.92	5/(4)	0	4	0	1	0	100
NGC 6304	-1.00/-0.59	21/(0)	0	0	0	0	0	101
NGC 6341/M92	0.91/-2.29	21/(20)	2	17	1	0	0	102,103
NGC 6333/M9	0.87/-1.72	20/(20)	0	17	1	1	1	104
NGC 6356	-1.00/-0.50	8/(3)	0	0	0	3	0	68,105
NGC 6352	-1.00/-0.70	3/(1)	0	0	0	1	0	68,106,107,
NGC 6366	-0.97/-0.82	1/(1)	0	1	0	0	0	108
NGC 6362	-0.58/-0.95	47/(37)	1	35	0	0	1	109,110,111
Haute P1	— /-1.50	15/(0)	0	0	0	0	0	
NGC 6380	— /-0.50	1/(0)	0	0	0	0	0	
Terzan 1	— /-0.35	4/(0)	0	0	0	0	0	112
NGC 6388	— /-0.60	29/(10)	0	10	0	0	0	68,113, 114,115
Pismis 26	— /-0.50	2/(0)	0	0	0	0	0	
NGC 6402/M14	0.65/-1.39	90/(61)	0	54	6	6	0	116

Table 1—Continued

Cluster	HBR/[Fe/H]	No./ (periods)	SX	RR	Cep or RVTau	SR or Red	Ecl	Ref
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
NGC 6401	— /-1.12	25/(0)	0	0	0	0	0	112
NGC 6397	0.98/-1.95	7/(6)	2	0	0	0	4	117,118
NGC 6426	0.53/-2.26	15/(14)	0	14	0	0	0	119,120
Terzan 5	-1.00/-0.28	4/(4)	0	1	0	2	1	121,122
NGC 6441	— /-0.53	37/(10)	0	10	0	0	0	115,123
NGC 6522	0.71/-1.44	1/(1)	0	1	0	0	0	124
NGC 6539	-1.00/-0.66	1/(0)	0	0	0	0	0	
NGC 6544	1.00/-1.56	2/(1)	0	1	0	0	0	125
NGC 6541	1.00/-1.83	1/(0)	0	0	0	0	0	126
NGC 6553	-0.34/-1.00	13/(3)	0	2	0	1	0	
NGC 6558	— /-1.44	15/(9)	0	9	0	0	0	127,128
IC 1276/Pal 7	— /-0.73	5/(1)	0	1	0	4	0	
NGC 6569	— /-0.86	19/(0)	0	0	0	0	0	129
NGC 6584	-0.15/-1.49	46/(42)	0	42	0	0	0	130,131
NGC 6624	-1.00/-0.42	4/(0)	0	0	0	0	0	132,133
NGC 6626/M28	0.90/-1.45	20/(15)	0	10	3	4	2	134,135,136
NGC 6638	-0.30/-0.99	61/(19)	0	13	0	6	0	137
NGC 6642	— /-1.35	18/(16)	0	16	0	0	0	138
NGC 6637/M69	-1.00/-0.71	7/(2)	0	0	0	2	0	
NGC 6652	-1.00/-0.96	5/(0)	0	0	0	0	0	139,140
NGC 6656/M22	0.91/-1.64	36/(24)	0	18	1	5	0	141,142,143
NGC 6681/M70	0.96/-1.51	3/(2)	0	2	0	0	0	144,145
NGC 6712	-0.64/-1.01	19/(14)	0	9	0	5	0	146

Table 1—Continued

Cluster	HBR/[Fe/H]	No./ (periods)	SX	RR	Cep or RVTau	SR or Red	Ecl	Ref
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
NGC 6715/M54	0.87/-1.59	94/(64)	0	61	2	0	1	147
NGC 6717	0.98/-1.29	1/(1)	0	1	0	0	0	148
NGC 6723	-0.08/-1.12	32/(28)	0	28	0	1	0	68,149,150
NGC 6752	1.00/-1.56	10/(7)	3	0	1	0	3	151,152
								153,154
NGC 6760	-1.00/-0.52	4/(0)	0	0	0	0	0	
NGC 6779/M56	0.98/-1.94	7/(4)	0	2	2	0	0	155
NGC 6809/M55	0.87/-1.81	37/(37)	24	13	0	0	0	156,157
NGC 6838/M71	-1.00/-0.73	26/(18)	3	0	0	2	13	88,158
NGC 6864/M75	-0.42/-1.32	17/(6)	0	6	0	3	0	159
NGC 6934	0.25/-1.54	86/(82)	1	78	0	1	2	160,161
NGC 6981/M72	0.14/-1.40	35/(25)	0	25	0	0	0	162
NGC 7006	-0.28/-1.63	72/(64)	0	62	0	1	0	163,164
NGC 7078/M15	0.67/-2.25	154/(104)	2	88	2	0	1	165,166,167
								168,169,170
								171,172
NGC 7089/M2	0.96/-1.62	33/(33)	0	29	4	0	0	173
NGC 7099/M30	0.89/-2.12	13/(3)	0	3	0	0	0	112
Pal 12	-1.00/-0.94	3/(0)	0	0	0	0	0	
Pal 13	-0.20/-1.65	4/(4)	0	4	0	0	0	
NGC 7492	0.81/-1.51	4/(4)	0	3	1	0	0	
TOTAL		2993(2220)	117	1842	60	117	96	

†ω Cen contains 5 spotted variables with periods that range from 3.3 days to 34 days. It also contains 2 possible ellipsoidal variables. Since variables of these types have only been identified in ω Cen, they are included in this column, but they are not plotted in Figure 1. There are only 3 SR/red variables in ω Cen.

References. — (1) Fox (1982); (2) Carney et al. (1993); (3) Edmonds et al. (1996); (4) Kaluzny et al. (1998b); (5) Kaluzny (1996); (6) Kaluzny et al. (1997a); (7) Lloyd Evans (1978); (8) Wehlau & Demers (1977); (9) Wehlau et al. (1977); (10) Liller (1975); (11) Wehlau et al. (1978); (12) Wehlau et al. (1982); (13) Walker (1998); (14) Liller (1976); (15) Clement et al. (1995a); (16) Pinto & Rosino (1977); (17) Clement & Hazen (1989); (18) Gratton & Ortolani (1984); (19) Borissova et al. (1998); (20) Borissova et al. (2000); (21) Lee (1977b); (22) Cacciari (1984a,b); (23) Clement (2000); (24) Kaluzny & Krzemiński (1993); (25) Kaluzny et al. (1995); (26) Clement et al. (1993); (27) Walker (1994); (28) Demers & Wehlau (1977); (29) Goranskij (1976); (30) Kopacki (2000); (31) Nemec et al. (1995a, 1995b); (32) Butler et al. (1978); (33) Fourcade et al. (1978); (34) Liller (1978); (35) Niss et al. (1978); (36) Jorgensen & Hansen (1984); (37) Kaluzny et al. (1996, 1997b,c); (38) Kholopov (1974, 1977); (39) Meinunger (1980); (40) Kadla & Geraschenko (1982); (41) Kaluzny et al. (1998a); (42) Corwin et al. (1999a); (43) Bakos et al. (2000); (44) Fourcade et al. (1975); (45) Liller & Lichten (1978a); (46) Gerashchenko et al. (1997); (47) Buonanno et al. (1984); (48) Mateo et al. (1990); (49) Nemec & Mateo (1990); (50) Corwin et al. (1999b); (51) Liller & Sawyer Hogg (1976); (52) Clement et al. (1979); (53) Clement et al. (1986); (54) Walker & Nemec (1996); (55) Wehlau (1990); (56) Wehlau et al. (1996); (57) Clement & Rowe (2001); (58) Kadla et al. (1987); (59) Kravtsov (1988, 1991, 1992); (60) Sandquist et al. (1996); (61) Brocato et al. (1996); (62) Reid (1996); (63) Yan & Reid (1996); (64) Drissen & Shara (1998); (65) Olech et al. (1999b); (66) Kaluzny et al. (1999, 2000); (67) Caputo et al. (1999); (68) Lloyd Evans & Menzies (1977); (69) Liller (1983a); (70) Liller & Lichten (1978b); (71) Alves et al. (2001); (72) Wehlau et al.

(1990); (73) Sujarkova & Shugarov (1981); (74) Lee (1977a); (75) Yao et al. (1981, 1988); (76) Yao (1986, 1987, 1991, 1993); (77) Cudworth & Rees (1990); (78) Shokin & Samus (1996); (79) Kaluzny et al. (1997d); (80) Liller (1981); (81) Hazen (1991); (82) Clement & Sawyer Hogg (1977a); (83) Clement & Shelton (1997); (84) Russev & Russeva (1979a,b); (85) Russeva & Russev (1980,, 1983) (86) Russeva et al. (1982) (87) Kadla et al. (1980); (88) Welty (1985); (89) Osborn (2000a,b); (90) Clement et al. (1988); (91) Malakhova et al. (1997a); (92) Carney et al. (1991); (93) Borrisova et al. (1997, 2001); (94) Liller (1977); (95) Clement et al. (1985); (96) Malikhova et al. (1997b); (97) Clement & Sawyer Hogg (1978); (98) Clement et al. (1980); (99) Stetson & West (1994); (100) Clement et al. (1982); (101) Hartwick et al. (1981); (102) Kadla et al. (1983); (103) Kopacki (2001); (104) Clement et al. (1984), Clement & Shelton (1996); (105) Clement & Sawyer Hogg (1977b); (106) Whitelock (1986); (107) Hesser (1980); (108) Harris (1993); (109) Clement et al. (1995b); (110) Mazur et al. (1999); (111) Olech et al. (2001); (112) Terzan & Rutily (1975); (113) Hazen & Hesser (1986); (114) Silbermann et al. (1994); (115) Pritzl et al. (2000); (116) Wehlau & Froelich (1994); (117) Kaluzny (1997); (118) Cool et al. (1998); (119) Clement & Nemec (1990); (120) Papadakis et al. (2000); (121) Spinrad et al. (1974); (122) Edmonds et al. (2001); (123) Layden et al. (1999); (124) Walker & Mack (1986); (125) Hazen (1993a); (126) Hazen (1994); (127) Hazen (1996); (128) Blanco & Blanco (1997); (129) Hazen-Liller (1985); (130) Millis & Liller (1980); (131) Samus et al. (1995); (132) Liller & Liller (1976); (133) Deutsch et al. (1999); (134) Wehlau & Sawyer Hogg (1982); (135) Wehlau & Butterworth (1991); (136) Rees & Cudworth (1991); (137) Rutily & Terzan (1977); (138) Hazen (1993b); (139) Hazen (1989); (140) Deutsch et al. (2000); (141) Wehlau & Sawyer Hogg (1977, 1978); (142) Marinchev (1983); (143) Kravtsov et al. (1994); (144) Liller (1983b); (145) Kadla et al. (1996); (146) Cudworth (1988); (147) Layden & Sarajedini (2000); (148) Goranskij (1978); (149) Menzies (1974); (150) Kovacs et al. (1986); (151) Cannon & Stobie (1973); (152) Lee (1974); (153) Thompson et al. (1999);

(154) Bailyn et al. (1996); (155) Wehlau & Sawyer Hogg (1985); (156) Olech et al. (1999a); (157) Pych et al. (2001); (158) Park & Nemec (2000); (159) Pinto et al. (1982); (160) Sawyer Hogg & Wehlau (1980); (161) Kaluzny et al. (2001); (162) Kadla et al. (1995); (163) Pinto & Rosino (1973); (164) Wehlau et al. (1999); (165) Chu (1977); (166) Chu et al. (1984); (167) Kadla et al. (1984); (168) Geffert et al. (1989); (169) Yao (1990), Yao & Qin (1993); (170) Silbermann & Smith (1995); (171) Butler et al. (1998); (172) Jeon et al. (2000); (173) Lee & Carney (1999a).

Table 2. Mean Periods of RR Lyrae Variables in Galactic Globular Clusters

Cluster	# of RR0	< P > (RR0)	# of RR1	< P > (RR1)	# of RR2	< P > (RR2)	# of RR01	< P > (RR01)	< P_f >
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
NGC 104	1	0.737	0		0		0		0.737
NGC 288	1	0.678	1	0.430	0		0		0.628
NGC 362	7	0.542	0		0		0		0.542
NGC 1261	13	0.555	5	0.328	0		0		0.523
NGC 1851	21	0.571	7	0.317	1	0.266	0		0.531
NGC 1904	2	0.685	1	0.335	0		0		0.607
NGC 2298	1	0.640	3	0.394	0		0		0.557
NGC 2419	24	0.655	6	0.380	0		1	0.407	0.624
NGC 2808	1	0.539	0		1	0.306	0		0.526
NGC 3201	72	0.554	3	0.338	2	0.274	0		0.547
NGC 4147	4	0.531	5	0.339	0		0		0.489
Rup 106	13	0.617	0		0		0		0.617
M68	13	0.613	17	0.390	0		12	0.397	0.554
NGC 4833	7	0.708	7	0.380	0		0		0.609
M53	29	0.649	27	0.351	2	0.309	0		0.562
NGC 5053	5	0.672	4	0.354	0		0		0.585
ω Cen	76	0.651	59	0.387	26	0.306	0		0.581
M3	145	0.555	27	0.345	5	0.286	5	0.358	0.537
NGC 5286	8	0.614	5	0.344	0		0		0.556
NGC 5466	13	0.646	5	0.382	2	0.262	0		0.592
NGC 5634	3	0.621	3	0.379	0		0		0.565
IC 4499	63	0.580	14	0.354	3	0.284	17	0.358	0.544
NGC 5824	7	0.624	0		0		0		0.624

Table 2—Continued

Cluster	# of RR0	< P > (RR0)	# of RR1	< P > (RR1)	# of RR2	< P > (RR2)	# of RR01	< P > (RR01)	< P_f >
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Pal 5	0		3	0.316	2	0.273	0		0.438
NGC 5897	3	0.828	2	0.437	2	0.345	0		0.688
M5	91	0.551	34	0.320	1	0.265	0		0.517
NGC 5946	2	0.651	0		0		0		0.651
NGC 5986	7	0.652	1	0.328	0		0		0.626
M80	4	0.651	2	0.366	0		0		0.598
M4	31	0.533	7	0.302	2	0.250	0		0.505
NGC 6139	3	0.662	1	0.417	0		0		0.636
M107	15	0.538	7	0.287	0		0		0.490
M13	1	0.750	3	0.358	1	0.313	0		0.543
NGC 6229	30	0.553	7	0.330	1	0.264	0		0.529
NGC 6235	2	0.600	1	0.352	0		0		0.557
M62	62	0.544	11	0.304	1	0.248	0		0.522
M19	1	0.507	0		0		0		0.507
NGC 6284	6	0.588	0		0		0		0.588
NGC 6293	2	0.600	2	0.353	0		0		0.537
M92	11	0.630	5	0.364	1	0.313	0		0.582
M9	8	0.638	9	0.342	0		0		0.543
NGC 6366	1	0.513	0		0		0		0.513
NGC 6362	18	0.547	15	0.299	2	0.251	0		0.477
NGC 6388	5	0.712	5	0.332	0		0		0.579
M14	39	0.564	10	0.335	5	0.320	0		0.540
NGC 6426	9	0.704	4	0.332	0		1	0.408	0.619

Table 2—Continued

Cluster (1)	# of RR0 (2)	< P > (RR0) (3)	# of RR1 (4)	< P > (RR1) (5)	# of RR2 (6)	< P > (RR2) (7)	# of RR01 (8)	< P > (RR01) (9)	< P_f > (10)
Terzan 5	1	0.60	0		0		0		0.60
NGC 6441	10	0.768	0		0		0		0.768
NGC 6522	1	0.564	0		0		0		0.564
NGC 6544	1	0.57	0		0		0		0.570
NGC 6553	2	0.526	0		0		0		0.526
NGC 6558	6	0.556	3	0.345	0		0		0.525
Pal 7	1	0.548	0		0		0		0.548
NGC 6584	34	0.560	8	0.304	0		0		0.531
M28	8	0.577	2	0.312	0		0		0.545
NGC 6638	1	0.666	11	0.307	1	0.308	0		0.439
NGC 6642	10	0.544	6	0.322	0		0		0.502
M22	10	0.632	8	0.361	0		0		0.567
M70	1	0.564	1	0.402	0		0		0.552
NGC 6712	7	0.557	2	0.338	0		0		0.534
M54	55	0.579	6	0.342	0		0		0.568
NGC 6717	1	0.575	0		0		0		0.575
NGC 6723	23	0.541	4	0.292	1	0.288	0		0.517
M56	1	0.906	1	0.423	0		0		0.736
M55	4	0.662	5	0.391	4	0.321	0		0.571
M75	3	0.531	3	0.271	0		0		0.447
NGC 6934	68	0.574	9	0.308	1	0.247	0		0.553
M72	24	0.547	1	0.353	0		0		0.544
NGC 7006	53	0.569	9	0.329	0		0		0.550

Table 2—Continued

Cluster	# of RR0	$< P >$ (RR0)	# of RR1	$< P >$ (RR1)	# of RR2	$< P >$ (RR2)	# of RR01	$< P >$ (RR01)	$< P_f >$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
M15	39	0.637	30	0.337	2	0.290	17	0.401	0.551
M2	17	0.725	9	0.345	3	0.298	0		0.621
M30	3	0.698	0		0		0		0.698
Pal 13	4	0.572	0		0		0		0.572
NGC 7492	1	0.805	1	0.292	1	0.280	0		0.556
TOTAL	1269	0.585	447	0.345	73	0.296	53	0.383	0.550